Fishery Data Series No. 09-71

Kanalku Lake Subsistence Sockeye Project: 2007 Annual Report

Note: This report was revised in May 2010 to correct errors in the mark-recapture analysis presented in the original report published in January 2010. In the original report, the mark-recapture estimate was used as our best estimate of the escapement. Correction of the mark-recapture analysis resulted in a significant change in that estimate, however, making it necessary to revise this report. We now present the weir count as our best estimate of the sockeye salmon escapement at Kanalku Lake in 2007.

by

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and

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May 2010

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 09-71

KANALKU LAKE SUBSISTENCE SOCKEYE PROJECT: 2007 ANNUAL REPORT

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ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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ABSTRACT

Residents of Angoon, Alaska, have long depended on Kanalku Lake sockeye salmon (*Oncorhynchus nerka)* for subsistence harvest due to the close proximity to the village and ease of access. High subsistence harvests in the 1990s combined with escapements of less than 300 fish in the early 2000s prompted concerns about the future productivity of the sockeye salmon stock returning to Kanalku Lake. In 2002, local residents and ADF&G agreed upon a voluntary reduction of subsistence harvest of sockeye salmon to help stocks rebuild. Since 2006, a traditional subsistence fishery for sockeye salmon in Kanalku Bay has been open under a shortened season; harvest remained low through 2007. In 2007 we operated a weir in Kanalku Creek to count sockeye salmon passage into the lake. A weir-to-spawning-grounds mark-recapture estimate was conducted and compared with the weir count and previous years' mark-recapture estimates. Biological data to determine age and length compositions were taken from sockeye salmon at the weir. Light and temperature profiles were taken in the lake throughout the season, and zooplankton was collected and analyzed for species composition, density, and biomass. The total escapement into Kanalku Lake in 2007, based on the weir count, was 461 sockeye salmon. This was somewhat disconcerting, after estimated escapements of over 1,000 spawners from 2004 to 2006 suggested a rebound in the population. The 2007 age composition was more similar to age data collected from 2001 to 2005, and was split between age-1.2 (37%) and age-1.3 (54%) fish, which was a change from the nearly single-aged run in 2006 (97% age-1.2).

Key words: sockeye salmon, *Oncorhynchus nerka*, subsistence, Kanalku Lake, escapement, weir, mark–recapture, limnology, zooplankton, Southeast Alaska

INTRODUCTION

Kanalku Lake sockeye salmon (*Oncorhynchus nerka)* have a long history of subsistence harvest by residents of Angoon. The use of Kanalku Bay by Angoon clans for harvesting sockeye salmon can be seen in the archaeological and historical record (de Laguna 1960; Moss 1989; Thornton et al. 1990; Goldschmidt and Haas 1998). After the adoption of statehood in Alaska, a non-commercial subsistence fishery was defined and harvest records are compiled under a permit system (Turek et al. 2006). Although Angoon residents can obtain subsistence fishing permits for other areas, including Sitkoh and Basket Bays, Kanalku Bay is preferred by Angoon residents due to its close proximity and ease of accessibility via sheltered waterways.

Quantitative records of subsistence effort and harvest of sockeye salmon in Kanalku Bay and Kanalku Creek, starting from 1985, have been obtained from subsistence fishing permits that were returned to ADF&G. After the fishing season, subsistence fishermen are required to turn in their permits with catch and area information to ADF&G before obtaining their permits for the subsequent year. These self-reported harvest data should be considered minimum estimates of actual harvest because in other areas, a tendency for under reporting has been observed (Conitz and Cartwright 2003; Lewis and Cartwright 2004; Lorrigan et al. 2004). Reported harvest of Kanalku Lake sockeye salmon averaged almost 1,300 fish annually during the 1990s, with a peak harvest of almost 1,700 fish in 1999 (Figure 1).

In the late 1990s, however, some resident fishermen began to notice a decline of sockeye salmon abundance in Kanalku Bay (Conitz and Cartwright 2002). Partly in response to this local observation, the ADF&G sockeye stock assessment program was implemented in 2001 to estimate the abundance of sockeye salmon spawners in Kanalku Lake. Estimated run sizes in 2001 and again in 2003 were alarmingly low, with escapement estimates of less than 275 adult sockeye salmon (Conitz and Cartwright. 2005). These low escapement estimates prompted ADF&G fisheries managers to consider an emergency closure or other conservation measures in the subsistence fishery. This voluntary slow-down was generally observed from the 2002 through

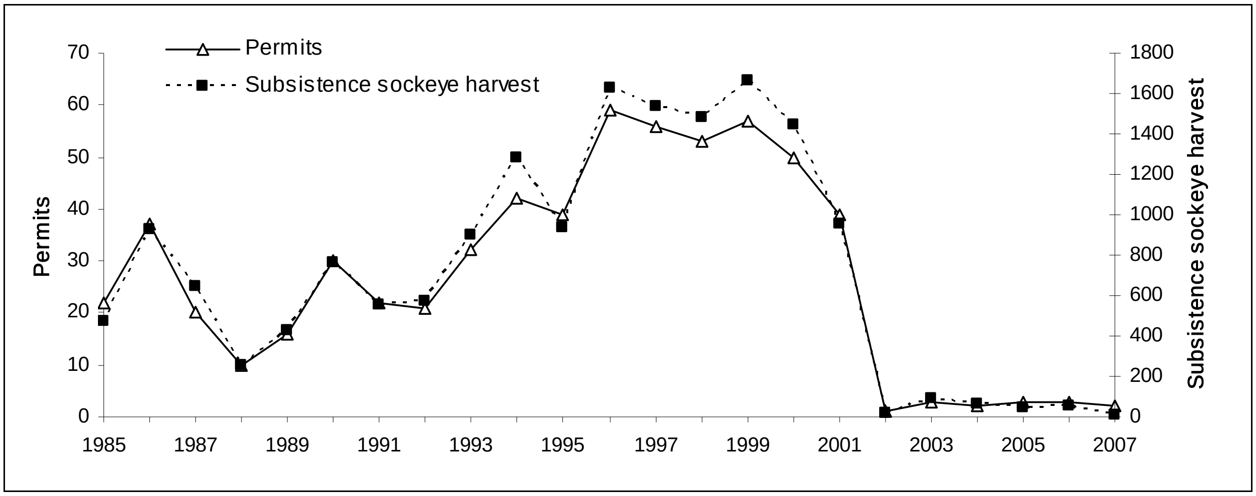

Figure 1.–Subsistence effort and harvest at Kanalku Bay and Creek reported on permits from 1985 to 2006 (ADF&G Division of Commercial Fisheries database, 2008).

the 2005 season. In 2006, the community resumed normal subsistence fishing at Kanalku Bay under a reduced season (Conitz and Burril 2008). Reported subsistence effort and harvest dropped dramatically in 2002, after the implementation of the voluntary closure, and harvest remained low through 2007 (Figure 1).

Escapement estimates of Kanalku Lake adult sockeye salmon spawners were above 1,000 fish from 2004 to 2006, which was seen as a sign of possible rebound. However, with the end of the voluntary harvest restrictions at Kanalku Bay, we expected subsistence fishing effort to gradually increase (Conitz and Burril 2008). Further monitoring of the escapement of sockeye salmon was considered essential to ensure an adequate spawning escapement past the fishery, as annual harvest levels similar to 1994–2001 would leave few fish to return to Kanalku Lake to spawn.

Another obvious impediment for the spawning sockeye salmon population in Kanalku Lake is the falls on the migration route up Kanalku Creek. In 2006, U.S. Forest Service personnel attempted to estimate the rate of natural mortality for sockeye salmon migrating past the falls by tracking radio-tagged fish; however, this effort was not successful (B. Van Alen, U.S. Forest Service, personal communication, 2007). In 2007, U.S. Forest Service biologists attempted a conventional tagging and mark–recovery program in a second attempt to estimate the natural mortality rate associated with migration over the falls.

Sockeye salmon escapement at Kanalku Lake may also be affected, to an unknown extent, by commercial fisheries in Chatham Strait, where they are harvested incidentally in purse seine fisheries targeting pink (*Oncorhynchus gorbuscha*) and chum (*Oncorhynchus keta*) salmon. The proportion of the total catch, if any, from Kanalku Lake stocks is unknown; however, the magnitude of these harvests is likely insignificant because of the early run timing of Kanalku Lake sockeye salmon relative to the opening date of the District 12 seine fishery (Geiger and ADF&G staff 2007).

In 2007, our primary goal was to estimate the escapement of spawning sockeye salmon into Kanalku Lake. Implementation of a weir near the outlet of Kanalku Lake in 2007 allowed us to count sockeye salmon entering the lake, observe the run timing, collect biological data, and estimate the total spawning population with a weir-to-spawning-grounds mark-recapture estimate. The mark-recapture study was our primary means of supporting the weir count and obtaining an accurate escapement estimate. Continued monitoring of Kanalku Lake sockeye salmon will allow fisheries biologists and managers to consider escapement trends in developing subsistence fishing management strategies, with the goal of optimizing future runs and ensuring sustainable spawning escapements and harvest opportunities for this small and vulnerable run.

OBJECTIVES

1. Count daily through a weir the number of salmonids, by species, entering Kanalku Lake from 25 June to 1 September, using conventional visual methods.
2. Estimate the escapement of sockeye salmon into Kanalku Lake with a mark–recapture study, marking fish at the weir and sampling for marked fish on the spawning grounds, so the estimated coefficient of variation is less than 15%.
3. Estimate the age, length, and sex composition of the Kanalku Lake sockeye salmon escapement.
4. Measure water column temperature and light profiles in Kanalku Lake through the season. Estimate zooplankton species composition, size, abundance, and biomass.

METHODS

STUDY SITE

Kanalku Lake (ADF&G stream no. 112-67-58/60; lat 57° 29.22'N long 134° 21.02'W) is about 20 km southeast of Angoon (Figure 2) and lies in a steep mountainous valley within the Hood-Gambier Bay carbonates ecological subsection (Nowacki et al. 2001). The u-shaped valley and rounded mountainsides are characterized by underlying carbonate bedrock and built up soil layers supporting a highly productive spruce forest, especially over major colluvial and alluvial fans. The watershed area is approximately 32 km^2, with one major inlet stream draining into the east end of the lake. The lake elevation is about 28 m. The lake surface area is about 113 hectares, with mean depth of 15 m, and maximum depth of 22 m (Figure 3). The outlet stream, Kanalku Creek, is 1.7 km long and drains into the east end of Kanalku Bay. In addition to sockeye salmon returning to the lake, large numbers of pink salmon (*O. gorbuscha*) spawn in the lower part of the outlet creek and intertidal area. A few coho (*O. kisutch*) and chum (*O. keta*) salmon spawn in the Kanalku system, and resident populations of cutthroat trout (*O. clarkii*), Dolly Varden char (*Salvelinus malma*), and sculpin (*Cottus sp.*) are found in Kanalku Lake. A waterfall, approximately 8–10 m high and about 0.8 km upstream from the tidewater, forms a partial barrier to migrating sockeye salmon. In 1970, ADF&G, working with the U.S. Forest Service, blasted resting pools and a small channel in the falls bedrock to assist the migrating salmon.

SOCKEYE SALMON ESCAPEMENT ESTIMATE

Weir Count

The Kanalku weir consisted of aluminum bipod supports anchored into the stream bottom, connected by three rows of stringers to extend across the entire stream bed, with pickets inserted through regularly spaced holes in the stringers into the stream bottom. Picket spacing was 1¾ inches (4.45 cm) on center of the pickets. Sandbags placed across the stream on both sides of the weir helped to stabilize the substrate and secure the pickets in place. A weir trap, sampling station, and catwalk were also constructed and attached to the weir. Technicians inspected the weir daily, and repaired any gaps or holes by pounding the pickets down further or blocked holes with sand bags. The integrity of the weir was also verified through a mark–recapture study.

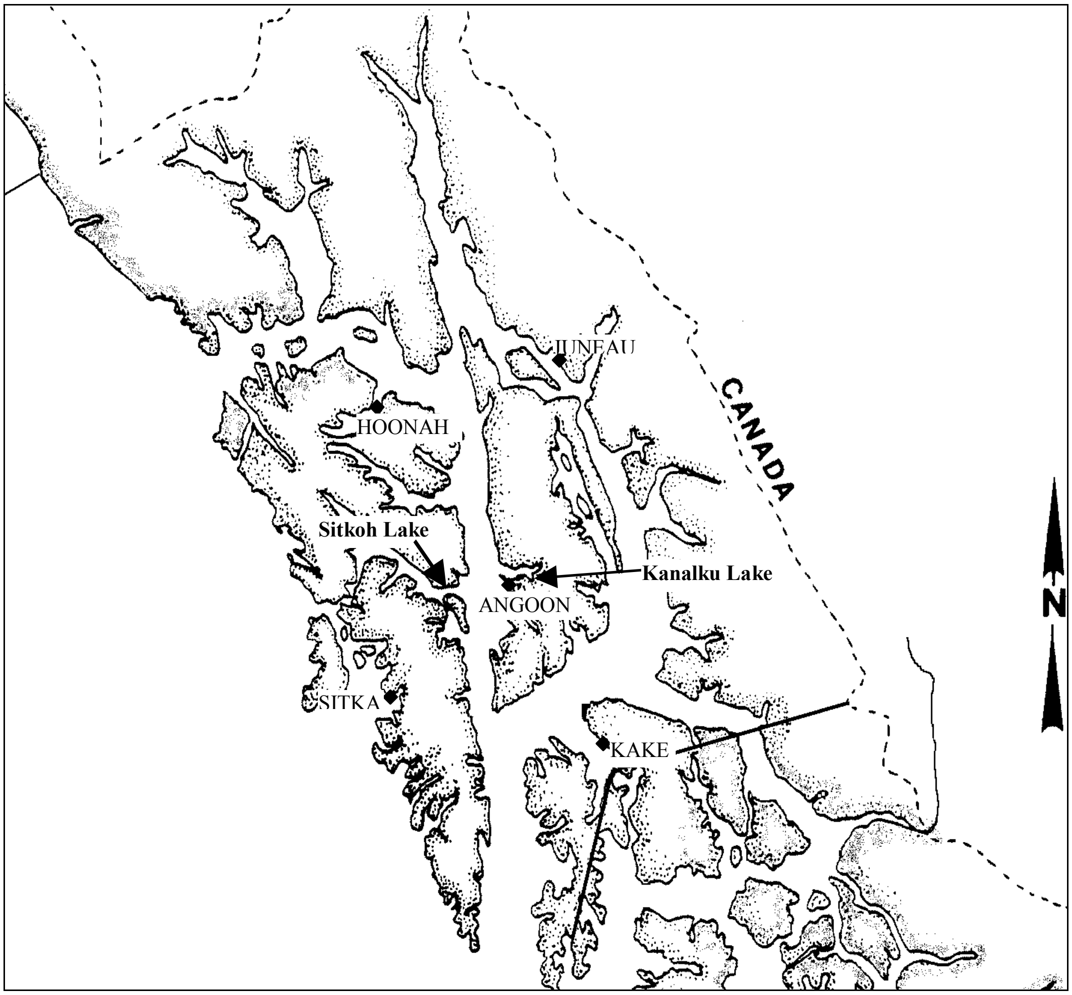

Figure 2.–Map of Southeast Alaska showing location of Kanalku Lake, and the village of Angoon.

In order to minimize handling of fish, fish were counted through the weir by pulling one or two pickets at the upstream side of the weir trap. We placed white sandbags on the bottom of the stream bed at this exit point to aid in fish identification. In addition to enumerating all fish by species, all sockeye salmon were enumerated as jacks or full-size adults. All sockeye salmon <400 mm in length were considered jacks.

Water level at a marker near the weir was measured to the nearest millimeter (mm), and air and water temperature were measured in °C, and recorded daily, along with observations of precipitation and weather. These observations were made at approximately the same time each morning.

Weir to Spawning Grounds Mark–Recapture

In addition to the weir count, the total population of adult spawning sockeye salmon was estimated using a stratified Petersen mark–recapture method. The mark–recapture study allowed

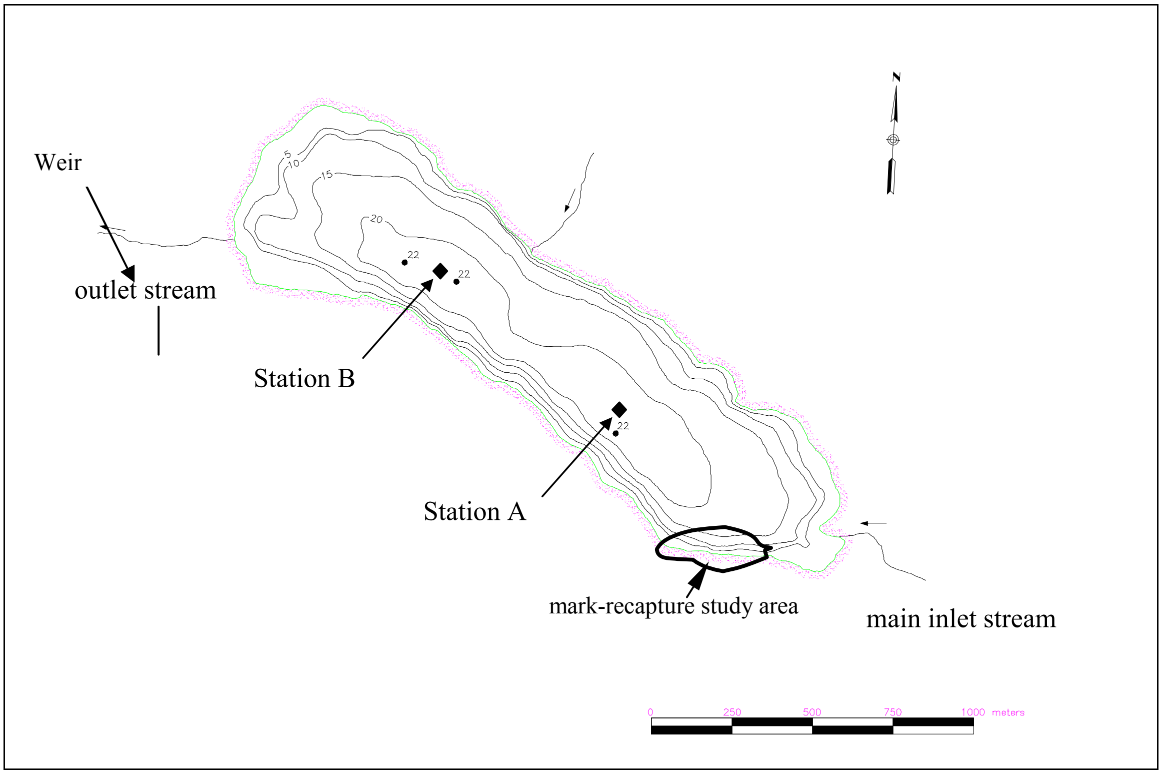

Figure 3.–Bathymetric map of Kanalku Lake, showing 5m depth contours, weir location, and the mark–recapture study area. Arrows indicate direction of stream flow.

us to determine if sockeye salmon passed through the weir undetected. Fish were marked at the weir with an adipose fin clip plus a uniquely-numbered tag which permitted post-season stratification of the marking sample. Technicians marked approximately 50% of the daily escapement of sockeye salmon passed through the weir. The adipose clip facilitated easy identification of marked fish and served as the primary mark in the event of tag loss. The T-bar tags were applied to the left side of the fish, inserted at the base of the leading dorsal fin rays. The tag number and date applied was recorded for each fish successfully tagged, and any fish marked only with the adipose clip was noted. Sockeye salmon that appeared unhealthy were enumerated and released without marks. In addition, sockeye jacks were not marked and were not included in the mark–recapture study.

Fish were sampled for mark (tag) recovery in the major spawning area along the east shore of Kanalku Lake adjacent to the mouth of the inlet stream with a beach seine. To date, no other spawning areas have been observed in Kanalku Lake. Sampling was conducted on 31 August, 11 September, and 20 September. Each sockeye salmon was examined for the adipose clip and tag. If present, the tag number was recorded; missing tags were also recorded as such. An opercular punch was applied to all sockeye salmon in these samples to ensure sampling without replacement during that day or later sampling events.

The two-sample Petersen model provides a simple method for estimating population size, based on the number of animals marked in the first sample, the number of animals subsequently sampled for marks in the second sample, and the number of marks recovered in the second sample (Seber 1982, p. 59; Pollock et al. 1990). Stratified mark–recapture models extend the two-sample Petersen method over two or more sampling events in both the marking (first) and mark–recovery (second) samples. Stratified models are widely used for estimating escapement of salmonids as they migrate into their spawning streams (Arnason et al. 1996). Spawning migrations may last for a month or more, during which time there can be substantial variation in biological parameters such as mortality rates. A fundamental assumption of the Petersen and related mark–recapture models is that capture probabilities for individual animals are equal (Pollock et al. 1990). This assumption can be met by satisfying the following conditions: 1) all fish have an equal probability of capture in the first sample (marking), 2) all fish have an equal probability of capture in the second sample (mark–recovery), and 3) fish mix completely between the first and second sample. In stratified sampling, if one or more of these conditions is met, the marking and recovery strata can generally be pooled, thereby providing the most precise estimate. However, if none of these conditions is met, the pooled estimate can be badly biased (Arnason et al. 1996).

To test for consistency of capture probabilities in the marking and recapture strata, two chi-square tests are commonly used. A test for equal capture probability in the first sample compares observed and expected numbers of marked and unmarked fish in each recapture stratum. A test for equal capture probability in the second sample, or equivalently, complete mixing, compares observed and expected numbers of those fish marked in the initial (marking) strata which were recaptured or not recaptured. These tests are provided in the Stratified Population Analysis System (SPAS) software that we used to analyze mark–recapture data and are labeled "equal proportions" and "complete mixing," respectively (Arnason et al. 1996). We considered a test statistic with p-value ≤ 0.05 to be "significant." If neither test statistic, or only one test statistic, was significant, we concluded all marking and all recapture strata could be pooled without significant risk of bias and the simple Petersen ("pooled-Petersen") estimator could be used. If both test statistics were significant, we concluded the pooled estimator had a significant risk of bias, and used the stratified Darroch estimator if it could be calculated. If the SPAS program was unable to converge to a solution for the Darroch estimator, we followed the guidelines and suggestions in Arnason et al. (1996) to search for a partial pooling scheme that would lead to a valid estimate. We also examined the data for any obvious deficiencies or discrepancies in sample sizes and recapture numbers, and considered events during the season, such as flooding or missed sampling dates, that may have led to inconsistencies.

If a valid Darroch estimate was generated, the 95% confidence interval bounds were used to judge the accuracy of the weir count. If the weir count fell within the 95% confidence interval bounds, it was considered accurate. If the weir count was below the lower 95% confidence interval bound, we considered the possibility that the weir count was inaccurate and some fish escaped into the lake undetected. In that case, the mark–recapture estimate, if unbiased, could be more accurate. A weir count above the 95% confidence interval bounds could only indicate the mark–recapture estimate was inaccurate, because the weir count, if free of counting errors, would always represent a minimum number of fish in the lake. If a valid Darroch estimate could not be generated, the weir count was accepted as the best estimate of at least minimum escapement.

Visual Survey

At the time of each sampling event, a visual survey of the entire lake shore was conducted. Crew members, using polarized sunglasses and hand counters ("tally whackers") visually counted the number of sockeye spawners from a boat traveling slowly around the margin of the lake. Individual counts were averaged for each survey. The boundaries of the mark–recapture study area were demarcated visually and with GPS readings, and the number of sockeye spawners within this study area were counted separately from other areas of the lake. The crew also surveyed the inlet stream up to approximately 1 km on 26 August and again on 20 September.

ADULT SOCKEYE SALMON POPULATION AGE AND SIZE COMPOSITION

Length, sex, and scale samples from 261 adult sockeye salmon were collected at the Kanalku weir and on the spawning grounds to describe the size and age structure of the population, by sex. Length of each fish was measured from mideye to tail fork, to the nearest millimeter (mm). Sex of the fish was decided by length and shape of the kype or jaw. Three scales were taken from the preferred area of each fish (INPFC 1963) and prepared for analysis as described by Clutter and Whitesel (1956).

Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g., 1.3 denotes a five-year-old fish with one freshwater and three ocean years; Koo 1962). The proportion in each age-sex group, and the seasonal age distribution weighted by week, was estimated along with its associated standard error, assuming a binominal distribution and using standard statistical techniques as described in common references (e.g., Thompson 1992).

LIMNOLOGY SAMPLING

Underwater light intensity was recorded at 0.5 m intervals from just below the surface to the depth where measured intensity was one percent of the sub-surface light reading, using an electronic light sensor and meter. The natural log (ln) of the ratio of light intensity just below the surface to light intensity at depth z, $\ln(I_0/I_z)$, was calculated for each depth. The vertical light extinction coefficient K_d was estimated as the slope of $\ln(I_0/I_z)$ versus depth. The euphotic zone depth (EZD) is defined as that depth at which light has attenuated to one percent of the intensity just below the lake surface (photosynthetically available radiation, 400–700nm) (Schindler 1971), and is calculated using the equation, EZD = 4.6205/ K_d (Kirk 1994).

Temperature was measured in degrees centigrade (ºC) with a Yellow Springs Instruments (YSI) Model 58[1] meter and probe. Measurements were made at one-meter intervals to the first 10 m or the lower boundary of the thermocline (defined as the depth at which the change in temperature decreased to less than 1ºC per meter). Below this depth, measurements were made at five-meter intervals.

Zooplankton samples were collected at two fixed stations using a 0.5 m diameter, 153 µm mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a maximum depth of two meters from the bottom, at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed at the ADF&G limnology laboratory in Kodiak, Alaska. Zooplankton samples were sub-sampled in the laboratory and identified to species or genus, counted and measured (Koenings et al. 1987). Density (individuals per m^2 surface area) was extrapolated from counts by taxon and the seasonal mean density was estimated by averaging densities across the sampling dates. The seasonal mean length of each taxon, weighted by density at each sampling date, was also estimated and used to calculate a seasonal mean biomass

1 Product names used in this report are included for scientific completeness, but do not constitute a product endorsement

estimate (weight per m^2 surface area) based on known length-weight relationships (Koenings et al. 1987).

RESULTS

SOCKEYE SALMON ESCAPEMENT ESTIMATE

Weir Count

The total number of adult sockeye salmon counted through the Kanalku Creek weir was 461 fish between 14 June and 31 August (Figure 4). The peak period of escapement occurred between 1 and 6 August, when 63% of the run was counted through the weir. The peak daily count occurred on 2 August when 151 adult sockeye salmon were passed through the weir, which represented 33% of the total escapement. No sockeye salmon jacks were observed at the weir. The weir remained intact through the entire season; we did not observe any obvious gaps or holes in the weir or any scouring below the weir which would have allowed fish to pass undetected. The water level throughout the season remained mostly constant.

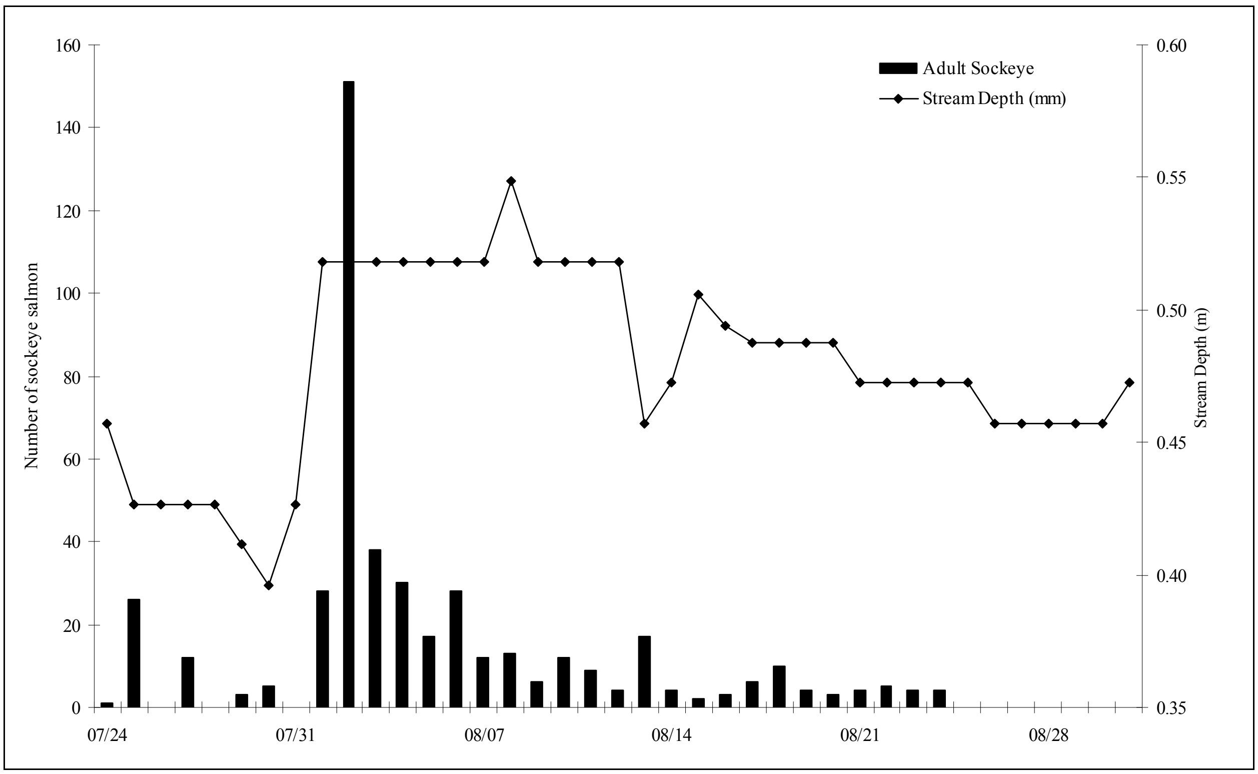

Figure 4.–Daily weir counts and water depth of Kanalku Lake outlet stream in 2007.

RESULTS

Weir to Spawning Grounds Mark-Recapture

The sampling crew captured and marked 203 adult sockeye salmon between 24 July and 31 August, 2007. Three recapture events were conducted on August 31, September 11, and September 20. During the three recapture efforts, 96 sockeye salmon were recovered on the spawning grounds, 35 of which were weir-marked fish. Of the 35 marked fish recovered, 5 (14%) had shed their T-bar tag. Tag loss was generally quite easy to determine from the presence of the adipose fin clip (primary tag) and the residual tag hole. Since we could not determine during which marking strata these fish were marked, we assumed 14% of the total number or weir-tagged sockeye salmon that we released had lost their tag. We then adjusted the marking strata accordingly (Table 1).

Table 1.–Numbers of sockeye salmon marked at the weir and numbers of spawners sampled for marks and numbers of recaptures at the spawning area in Kanalku Lake in 2007.

Marking stratum end date	Number marked	Count at weir	Marks recovered by sampling date			Total marks recovered	Proportion of marks recovered
			31-Aug	11-Sep	20-Sep		
4-Aug	73	294	4	10	2	16	0.19
24-Aug	101	167	1	12	1	14	0.12
Totals	174	461	5	22	3	96	
Number sampled			15	75	6		
Proportion marked in samples			0.33	0.29	0.50		

Recapture samples were stratified by sampling date (Table 1). To determine the appropriateness of pooling strata, consistency chi-square tests were performed. No violations were detected for the assumptions of equal probability of capture in the first event (i.e., fish marked in a given stratum had an equal probability of recovery in either recapture event; $X^2 = 1.08$, $df = 2$, $p = 0.58$) or the assumptions of complete mixing or equal probability of capture in the second event (i.e., recapture probabilities were different for fish marked in different strata; $X^2 = 1.93$, $df = 1$; $p = 0.17$). Therefore, we pooled the data and calculated a pooled-Peterson estimate of approximately 550 adult sockeye salmon, with a 95% confidence interval of approximately 430 to 740 fish and a coefficient of variation of 13.7%. The weir count of 461 sockeye salmon fell within the confidence interval bounds of the mark-recapture estimate; therefore, we will use the weir count of 461 adult sockeye salmon as the best estimate of the escapement in 2007.

Visual Survey

Visual surveys were conducted prior to all recapture events in Kanalku Lake from 31 August through 20 September 2007. The highest count of sockeye salmon in the study area was made on 31 August with an average count of 160 sockeye salmon (Table 2). Nearly all sockeye salmon seen on the surveys were within the study area spawning grounds. On both 31 August and 11 September the crew surveyed approximately 1 km of the main inlet stream to Kanalku Lake, and no sockeye salmon were observed spawning in the stream.

Table 2.–Visual counts of sockeye spawners in Kanalku Lake, 2007, comparing numbers counted inside designated study area with total counts for the lake.

Date	Average Count within Study Area	Average count for Whole Lake	Proportion in the Study Area
31 Aug	160	160	1.00
9 Sep	94	96	0.98
20 Sep	19	19	1.00

ADULT SOCKEYE SALMON POPULATION AGE AND SIZE COMPOSITION

During the 2007 season, 261 sockeye salmon were sampled for scales, sex, and length, both at the weir and on the spawning grounds in Kanalku Lake. Of these, the age was determined for 215 fish. Age class 1.2 and 1.3 accounted for 91% of the aged fish. The other 9% of the fish sampled were mostly age class 2.2 fish and a few 2.3 age class sockeye salmon (Table 3).

The average mid-eye-to-fork length of age-1.2 sockeye salmon in the Kanalku Lake spawning population was 488 mm in 2007 (Table 4). Age-1.3 fish, which spent an additional year in saltwater, were larger, averaging 551 mm. The lengths of age-2.2 sockeye salmon averaged 493 mm, which is similar to age-1.2 fish which also spent two years in saltwater. The few age-2.3 fish (n=3) that we sampled had a mean length of 535 mm.

Table 3.–Age composition of adult sockeye salmon in Kanalku Lake escapement by sex, and age class percentages weighted by weekly escapement.

	Brood Year by Age Class				
	2003	2002		2001	
Sampling Strata	1.2	1.3	2.2	2.3	Total Aged
Male					
Sample size	28	89	6	1	124
Percent	13%	41%	3%	0%	58%
Std. error	2.3%	3.4%	1.1%	0.5%	3.4%
Female					
Sample size	51	28	11	1	91
Percent	24%	13%	5%	0%	42%
Std. error	2.9%	2.3%	1.5%	0.5%	3.4%
All Fish					
Sample size	79	117	17	2	215
Percent	36.7%	54.4%	7.9%	0.9%	100%
Std. error	3.3%	3.4%	1.8%	0.7%	0%
Weighted percentages by age class, all fish					
	33.1%	59.4%	6.3%	1.3%	
Estimated number in escapement, by age class					
	152	274	29	6	

Table 4.–Mean fork length (mm) of adult sockeye salmon in the Kanalku Lake escapement by sex and age.

	Brood Year, by Age Class				
	2003	2002		2001	
Sampling Strata	1.2	1.3	2.2	2.3	All ages
Male					
Mean length (mm)	494	553	511	530	537
Std. error	4.9	2.2	6.4		3.0
Sample size	28	89	6	1	124
Female					
Mean length (mm)	485	546	484	540	504
Std. error	3.1	3.4	9.7		3.8
Sample size	51	28	11	1	91
All fish					
Mean length (mm)	488	551	493	535	523
Std. error	2.7	1.9	7.3	5.0	2.6
Sample size	79	117	17	2	215

Limnology Sampling

Light and Temperature Profiles

Light and Temperature profiles were measured on 10 July, 15 August, and 27 September, 2007. The euphotic zone depth (EZD) was deepest on 15 August at 16.4 m, and became 3 m shallower by 27 September (Table 5). Nearly uniform temperature was found on 10 July between about 6˚C and 10˚C indicating little stratification in the water column well into the summer. A slight thermocline developed by the 15 August sampling date. In 27 September, the observed temperature was near 10˚C throughout the water column at Kanalku Lake (Figure 5).

Table 5.–Euphotic zone depths at Kanalku Lake, 2007.

Date	Depth (m)
10 Jul	15.0
15 Aug	16.4
27 Sep	13.5
Seasonal mean	15.0

Secondary Production

The zooplankton composition by number in Kanalku Lake was dominated by the cladocerans *Bosmina* and *Daphnia* in 2007 (Table 6). Due to its larger size, *Holopedium* comprised the largest percentage of the total biomass, about 30%, followed by *Daphnia* and *Bosmina*. Although *copepod nauplii* increased exponentially throughout the season, numbers of all other taxa were highest during August and declined through September. Because sampling did not occur until more than two months into the growing season, the seasonal means from Kanalku Lake in 2007 may not accurately represent the actual zooplankton abundance and biomass over the entire season.

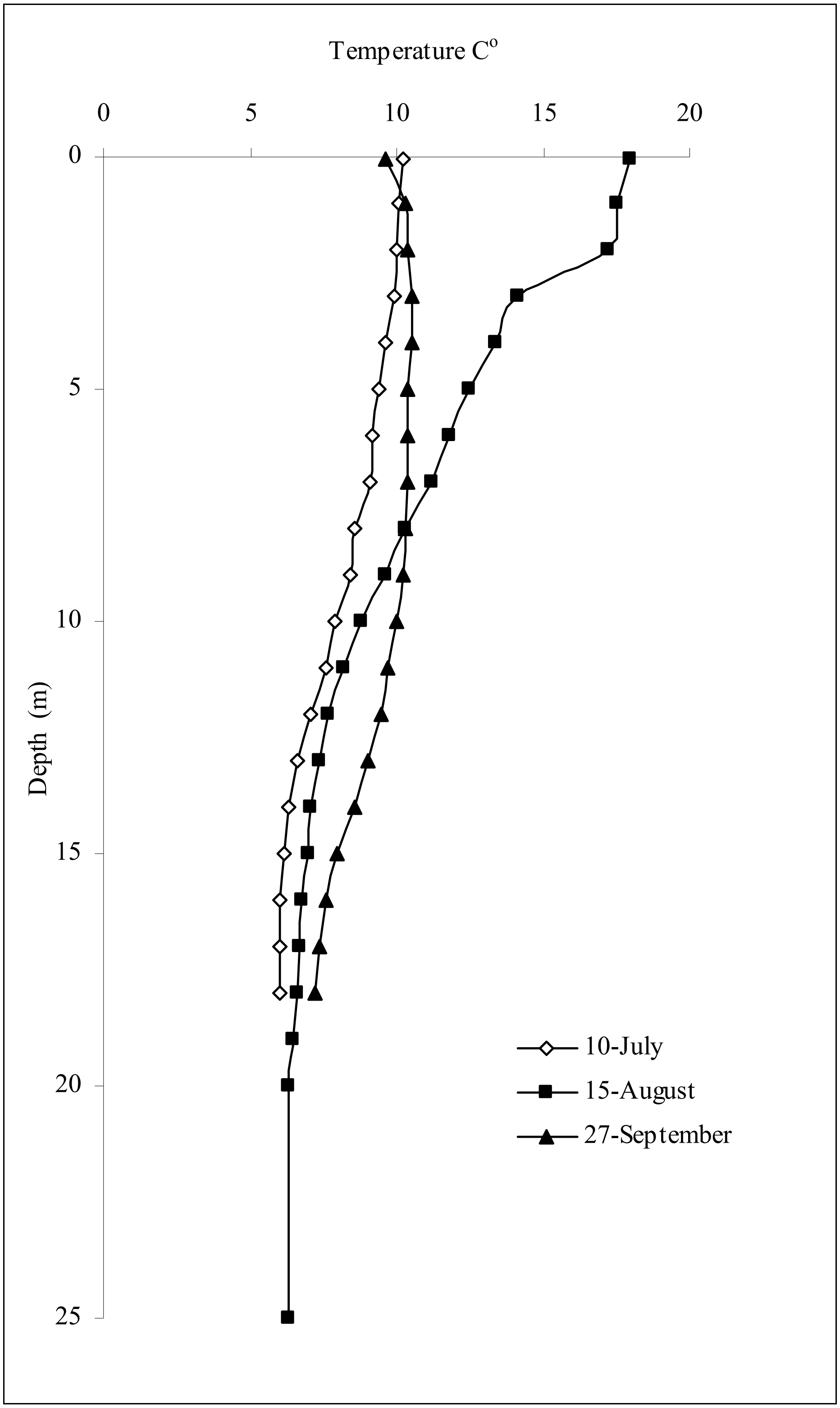

Figure 5.–Water column temperature profiles in Kanalku Lake, 2007.

Table 6.–Zooplankton mean weighted densities, biomass, and lengths for Kanalku Lake, 2007.

	Density (number/ m^2) by date			Seasonal mean density		Seasonal weighted mean length	Seasonal weighted mean biomass	
Zooplankton	10 Jul	16 Aug	27 Sep	Number/m^2	Percentage	(mm)	Mg/m^2	Percentage
Epischura	1,657	4,929	1,784	2,790	2.9%	1.41	103.2	10.1%
Cyclops	2,932	2,889	6,053	3,958	4.1%	0.76	27.1	2.7%
Ovigerous *Cyclops*	5,608	2,379	0	2,662	2.8%	1.16	39.9	3.9%
Copepod nauplii	1,275	11,553	39,315	17,381	18.0%			
Diaptomus	9,177	2,209	255	3,880	4.0%	1.16	75.8	7.4%
Ovigerous *Diaptomus*	127	340	0	156	0.2%	1.22	3.7	0.4%
Bosmina	10,326	43,502	32,173	28,667	29.7%	0.51	214.8	21.0%
Ovigerous *Bosmina*	128	170	1465	588	0.6%	0.72	9.0	0.9%
Daphnia longiremis	13,636	33,476	11,404	19,505	20.2%	0.79	164.7	16.2%
Ovigerous *Daphnia l.*	3,568	6,627	1,338	3,844	4.0%	1.15	72.6	7.1%
Holopedium	7,903	15,468	0	7,790	8.1%	0.98	266.0	26.1%
Ovigerous *Holopedium*	128	2,380	0	836	0.9%	1.18	42.7	4.2%
Immature Cladocera	4,716	6,626	2,357	4,566	4.7%			
Totals				96,623			1,019	

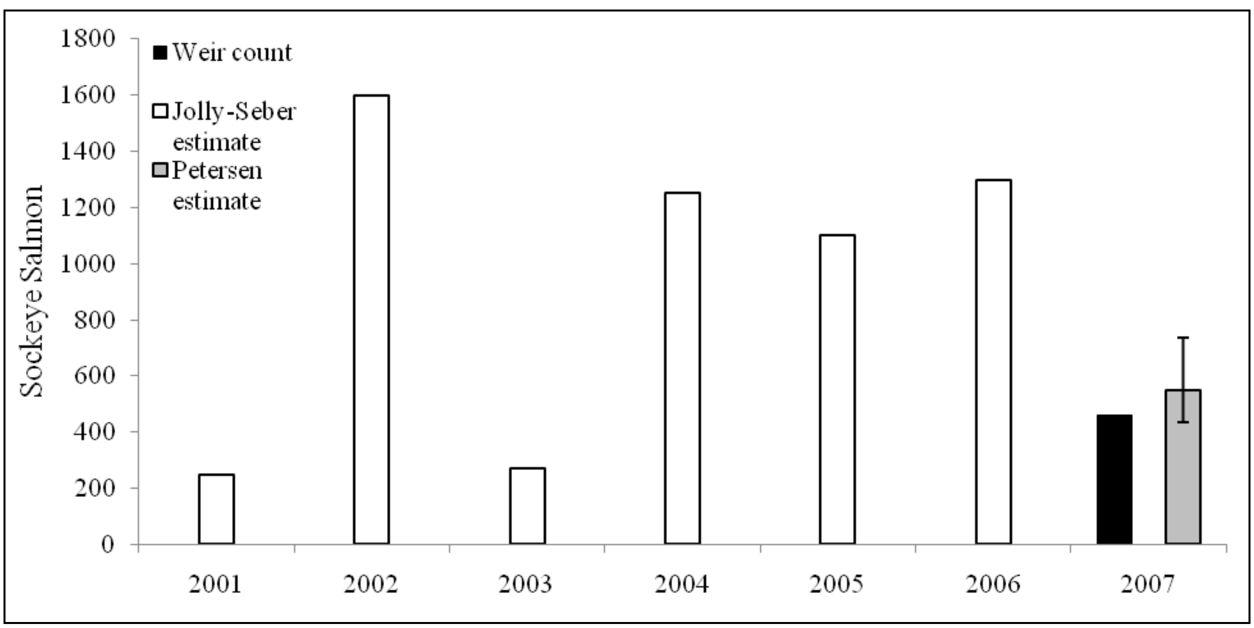

Figure 6.–Estimated adult sockeye salmon escapements from 2001 to 2007. Error bars represent the 95% confidence interval of the 2007 Petersen mark-recapture estimate.

DISCUSSION

Our best estimate of the escapement at Kanalku Lake in 2007 was obtained from the weir count of 461 adult sockeye salmon. The mark-recapture estimate of 550 sockeye salmon met our criteria for precision (CV <15%), and the weir count fell within the 95% confidence interval of the mark-recapture estimate (430–740 sockeye salmon). The difference between the weir count and the mark-recapture estimate could have resulted from bias, either in the weir count or the mark-recapture study. Loss of tagged fish through mortality or change in behavior prior to reaching the spawning grounds would result in a mark-recapture estimate that is biased high (Seber 1982, Schwarz and Taylor 1998). Such loss of tags could have occurred through handling effects at the weir, injuries and stress incurred as the fish attempted to scale the partial barrier falls, or predation on marked fish. In addition, ample mark-recapture samples were difficult to obtain in the lake due to the low numbers of fish and woody debris and steep drop-offs in the spawning area that made beach seining difficult. The spawning period is very short at Kanalku Lake, lasting only about four weeks (Conitz and Cartwright 2003, Burril and Conitz 2007), and poor weather conditions further hampered the recapture effort in 2007, limiting us to only three weeks of sampling. Conversely, salmon weirs must be rigorously maintained or fish will pass through the weir uncounted, resulting in a weir count that is biased low. It is possible that sockeye salmon passed the weir without being counted, though no problems with the weir structure were encountered in 2007, the weir was operated over the entire migration period, daily escapements were very low, and no other species of salmon reached the weir (Appendix 1). Although the weir count and the mark-recapture estimates differ slightly, both showed that the overall escapement in 2007 was very poor.

The 2007 weir count of 461 adult sockeye salmon fell roughly in the middle of the escapement estimates obtained between 2001 and 2006; this low estimate gives reason for continuing concern about the future of the population (Figure 6). Quantitative records of past escapements only date to 2001, when our monitoring program began, at which point the stock was in an obvious state of decline. Apart from the poor escapements in 2001 and 2003, our estimates have shown an average escapement of 1,300 sockeye salmon at Kanalku Lake. It is difficult to say what the 2007 escapement of 461 sockeye salmon means to the health of the fishery. There is simply not enough historical data to establish what a “good” or even “normal” escapement into Kanalku Lake should be. Nonetheless, an escapement of less than 1,000 sockeye spawners should justify concern over the future stock, especially considering that the average reported subsistence harvest, which is a minimum estimate, from 1994 to 2001 was over 1,300 fish. However, we cannot rely on harvest data to serve as an index of escapement due to the influence the partial barrier falls have on sockeye salmon migration. Although overharvest by subsistence fishermen or incidental landings by purse seiners in Chatham Strait could possibly be root causes of the low escapements observed in recent years, environmental factors may also be of significant importance to the stock.

2007 was the second year since 2002 that ADF&G managers did not rely on voluntary measures within the Angoon community to reduce harvest of sockeye salmon in the Kanalku Lake system. As in 2006, ADF&G set the harvest season to start on the date just after the historical peak run timing observed from 1985 to 2001. Harvest of sockeye salmon in Kanalku Bay was very low in 2007, with only 2 permits reporting a total catch of 10 sockeye salmon (Figure 1). Although this reported harvest may not be an accurate representation of the total subsistence harvest in this fishery, it does indicate that the harvest level at Kanalku Bay was relatively low compared with the escapement and very much less than the magnitude of harvests reported in the 1990s and early 2000s. This suggests that residents of Angoon are either going without sockeye salmon or harvesting them elsewhere. It is also clearly apparent that the Kanalku sockeye salmon stock is not supporting a sufficient level of harvest for subsistence needs.

Since our escapement monitoring efforts began in 2001, it has been noted that aquatic weeds have been expanding around the spawning area in Kanalku Lake. The easternmost section of the spawning area, which spawning sockeye salmon occupied in years past, is now inundated by weed growth (Conitz and Burril 2008). No evidence of a cause-and-effect relationship between recent weed growth and poor escapements exists, and continued monitoring of the spawning area at Kanalku Lake would be needed in order to draw any conclusions about the situation. In 2007, the inlet stream was again not used by sockeye spawners. No spawning sockeye salmon were found in the inlet stream despite two separate surveys conducted during the field season. Although it appears well suited for spawning, few sockeye salmon have ever been observed in the creek during previous seasons (Conitz and Burril 2008). It is also possible that the falls on Kanalku Creek are a major factor in reducing the sockeye salmon escapement into Kanalku Lake. Although U.S. Forest Service again attempted to determine the mortality rate at the falls in 2007, the relationship between the number of sockeye salmon returning to Kanalku Bay and the total size of the spawning population in the lake remains largely unknown.

The age composition of sockeye salmon at Kanalku Lake in 2007 showed a significant shift from that of the 2006 run, where 97% of the fish sampled were age-1.2. The 2007 age composition was similar to the 2001 to 2005 escapements, when the majority of the sockeye salmon were age-1.2 and age-1.3, with a few additional age-2.2 and age-2.3 fish (Burril and Conitz. 2007). The age diversity observed in 2007 is still low, however, and we believe this is a direct consequence of the very low spawning population of only 250 sockeye salmon observed in 2001 (Table 7; Conitz and Cartwright. 2005).

Table 7.–Totals of known-age sockeye salmon returns to Kanalku Lake from brood year 2001.

	Year of Return, by Age Class				
	2005		2006	2007	
	1.2	2.1	1.3	2.3	Total
Number Returned	322	3	10	2	337

Zooplankton and limnology sampling in 2007 provided evidence that prey availability for sockeye fry was not a limiting factor. From 2001 to 2003, Kanalku Lake consistently contained a higher-than-average seasonal mean biomass and density of zooplankton compared to more than a dozen other sockeye-producing lakes in Southeast Alaska (see Appendix E in Conitz and Cartwright. 2005), and these measures were again high for Kanalku Lake in 2007. Moreover, Kanalku Lake has supported a high seasonal mean biomass and density of *Daphnia,* the preferred prey of juvenile sockeye salmon, when compared to other sockeye-bearing lakes, such as Hetta Lake, which supports much larger runs of sockeye salmon (Cartwright et al. 2005). The large population of *Daphnia* in Kanalku Lake is indicative of low predation by foraging sockeye fry, and suggests that Kanalku Lake could likely support a much larger population of sockeye salmon (Cartwright et al. 2005).

Estimating annual sockeye salmon escapement into Kanalku Lake continues to be a priority for the management of Angoon area subsistence sockeye fisheries. With the end of voluntary restrictions on subsistence harvest in Kanalku Bay, we expect fishing effort to gradually increase and, therefore, monitoring is essential to ensure adequate spawning escapement past the fishery. Annual observations of the spawning escapement may motivate all parties to conserve and rebuild this run. In the meantime, further cooperation with U.S. Forest Service efforts in obtaining a reliable natural mortality estimate of returning adult sockeye salmon at the Kanalku Creek falls remains an important objective for continuing studies. Extension of the weir and mark–recapture studies over the next few seasons will give interested parties more confidence in our escapement estimates and contribute to a high-quality, long-term data set for this small and vulnerable sockeye salmon population.

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APPENDIX

Appendix A.–The 2007 Kanalku Lake weir counts by species, and daily water temperature and depth at Kanalku Lake's outlet stream.

Date	Water depth (m)	Water temperature (°C)	Number of Sockeye	
			Daily counts	Cum. counts
24 Jun	457	12.0	0	0
25 Jun	457	12.0	0	0
26 Jun	457	11.0	0	0
27 Jun	518	12.0	0	0
28 Jun	518	12.0	0	0
29 Jun	518	11.0	0	0
30 Jun	518	11.0	0	0
1 Jul	518	12.0	0	0
2 Jul	518	12.0	0	0
3 Jul	518	12.0	0	0
4 Jul	518	12.0	0	0
5 Jul	579	12.0	0	0
6 Jul	564	12.0	0	0
7 Jul	518	12.0	0	0
8 Jul	457	12.0	0	0
9 Jul	457	13.0	0	0
10 Jul	549	12.0	0	0
11 Jul	579	11.0	0	0
12 Jul	610	11.0	0	0
13 Jul	579	12.0	0	0
14 Jul	579	11.0	0	0
15 Jul	518	12.0	0	0
16 Jul	518	11.0	0	0
17 Jul	457	12.0	0	0
18 Jul	457	13.0	0	0
19 Jul	457	11.0	0	0
20 Jul	427	11.0	0	0
21 Jul	427	11.0	0	0
22 Jul	427	13.0	0	0
23 Jul	427	13.0	0	0
24 Jul	457	12.0	1	1
25 Jul	427	15.0	26	27
26 Jul	427	14.0	0	27
27 Jul	427	14.0	12	39
28 Jul	427	14.0	0	39
29 Jul	411	14.0	3	42
30 Jul	396	14.0	5	47
31 Jul	427	14.0	0	47

–continued–

Appendix A.–Page 2 of 2.

Date	Water depth (m)	Water temperature (^oC)	Number of Sockeye	
			Daily counts	Cum. counts
1 Aug	518	15.0	28	75
2 Aug	518	15.0	151	226
3 Aug	518	15.0	38	264
4 Aug	518	15.0	30	294
5 Aug	518	15.0	17	311
6 Aug	518	14.5	28	339
7 Aug	518	14.5	12	351
8 Aug	549	14.5	13	364
9 Aug	518	15.0	6	370
10 Aug	518	15.0	12	382
11 Aug	518	15.0	9	391
12 Aug	518	15.0	4	395
13 Aug	457	16.0	17	412
14 Aug	472	16.0	4	416
15 Aug	506	16.0	2	418
16 Aug	494	14.0	3	421
17 Aug	488	14.0	6	427
18 Aug	488	17.0	10	437
19 Aug	488	17.0	4	441
20 Aug	488	17.0	3	444
21 Aug	472	17.0	4	448
22 Aug	472	17.0	5	453
23 Aug	472	17.0	4	457
24 Aug	472	16.5	4	461
25 Aug	472	16.0	0	461
26 Aug	457	16.0	0	461
27 Aug	457	16.0	0	461
28 Aug	457	17.0	0	461
29 Aug	457	17.0	0	461
30 Aug	457	17.0	0	461
31 Aug	472	17.0	0	461